ERDC/CERL TR-01-32

US Army Corps of Engineers®
Engineer Research and Development Center

Site Evaluation for Application of Fuel Cell Technology

Naval Hospital—Marine Corps Air Ground Combat Center Twentynine Palms, CA

Michael J. Binder, Franklin H. Holcomb, and William R. Taylor

March 2001

Construction Engineering Research Laboratory

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Foreword

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DoD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

This report documents work done at Naval Hospital B Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, CA. Special thanks is owed to the Naval Hospital at Twentynine Palms points of contact (POCs), Stu Hammond and Luke Wren, for providing investigators with access to needed information for this work. The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael J. Binder. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations, CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration Program, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at Naval Hospital B Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms, CA along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (Table 1).

Objective

The objective of this work was to evaluate Naval Hospital at Twentynine Palms as a potential location for a fuel cell application.

Approach

On 8 and 9 December 1993, Science Applications International Corporation (SAIC) visited Twentynine Palms Marine Corps Base (the site) to investigate it as a potential location for a 200 kW phosphoric acid fuel cell. This report presents an overview of information collected at the site along with a conceptual fuel cell installation layout and potential benefits. The Appendix to this report contains a copy of the site evaluation form filled out at the site.

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Pine Bluff Arsenal, AR	TR 00-15
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Fort Bliss, TX	TR 01-13
Fort Huachuca, AZ	TR 01-14
Naval Air Station Fallon, NV	TR 01-15
Construction Battalion Center (CBC), Port Hueneme, CA	TR 01-16
Fort Eustis, VA	TR 01-17
Watervliet Arsenal, Albany, NY	TR 01-18
911th Airlift Wing, Pittsburgh, PA	TR 01-19
Westover Air Reserve Base (ARB), MA	TR 01-20
Naval Education Training Center, Newport, RI	TR 01-21
U.S. Naval Academy, Annapolis, MD	TR 01-22
Davis-Monthan AFB, AZ	TR 01-23
Picatinny Arsenal, NJ	TR 01-24
U.S. Military Academy, West Point, NY	TR 01-28
Barksdale Air Force Base (AFB), LA	TR 01-29
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Nellis AFB, NV	TR 01-31
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
934th Airlift Wing, Minneapolis, MN	TR 01-38
Laughlin AFB, TX	TR 01-41
Fort Richardson, AK	TR 01-42
Kirtland AFB, NM	TR 01-43
Subase New London, Groton, CT	TR 01-44
Edwards AFB, CA	TR 01-Draft
Little Rock AFB, AR	TR 01-Draft
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 01-Draft
U.S. Army Soldier Systems Center, Natick, MA	TR 01-Draft

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mi	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

Twentynine Palms is located approximately 150 mi east of Los Angeles, California and is approximately 50 mi northeast of Palm Springs. The location is in a high desert environment where temperatures are usually over 100 °F during the summer months. Winter temperatures can go as low as the 20s or 10s (°F) at night.

The Site has a new Naval hospital that opened in early 1993. The hospital is a 190,000 sq ft facility with 39 patient beds and various clinic facilities. The facility operates 24 hr/day. The hospital was the only facility deemed feasible for a fuel cell installation at the Site. Originally, a barracks facility was thought to be a potential location, but it is slated to be torn down in 2 to 3 years.

The electrical energy consumption of the hospital is presented in Table 2. Since it is a new building, energy data were not available for a full year. For the months of August through November, the average kW load of the facility was 347 kW; however, the hospital is still growing. Table 3 lists engineering projections of peak loads by month and period (on-peak, off-peak, shoulder periods). The annual peak load was estimated at about 930 kW.

Table 4 lists data on building gas consumption. From April through October, the average hourly gas consumption was about 710,000 Btu/hr. It is estimated that 95 percent of the gas use is used for domestic hot water and space heating.

Table 2. Hospital facility electricity consumption.

Date	Billing Days	kWh	Average kW
Aug 93	34	296,000	363
Sep 93	30	208,000	289
Oct 93	29	223,200	321
Nov 93	32	314,000	409

Table 3. Estimated hospital peak electric demand (kW).

Month	Demand kW		
	On-Peak	Off-Peak	Mid-Peak
January	558	577	583
February	568	578	586
March	587	590	662
April	661	594	697
May	691	689	747
June	794	712	768
July	906	740	782
August	934	749	914
September	795	714	763
October	700	611	728
November	638	591	671
December	559	587	584
Source: by Anderson, Debartolo, Pan, Inc.			

Table 4. Hospital facility natural gas consumption.

Date	Billing Days	Therms	Avg. Btu/hr
Apr 93	29	6,792	975,862
May 93	34	4,652	570,098
Jun 93	30	2,972	412,778
Jul 93	28	5,252	781,548
Aug 93	34	5,219	639,583
Sep 93	27	4,901	756,327
Oct 93	30	6,248	867,778
Nov 93	30	10,740	1,491,667
Dec 93	31	12,684	1,704,839

Site Layout

The mechanical rooms are located at one end of the building on the ground floor. Approximately 40 yd from the mechanical room across a landscaped lot lies a 9,000 sq ft outdoor equipment yard. In this yard are three 1,000 kW backup generator sets, an enclosed electrical room, two electrical transformers, a large cooling tower, water pumps, and an emergency fire system. Between the mechanical rooms and the equipment yard are under ground pipes and cables. Inside the two mechanical rooms are centrifugal chillers and steam boilers. The specifics of the systems are discussed in the following sections. Figure 1 shows the site layout for the hospital and equipment yard.

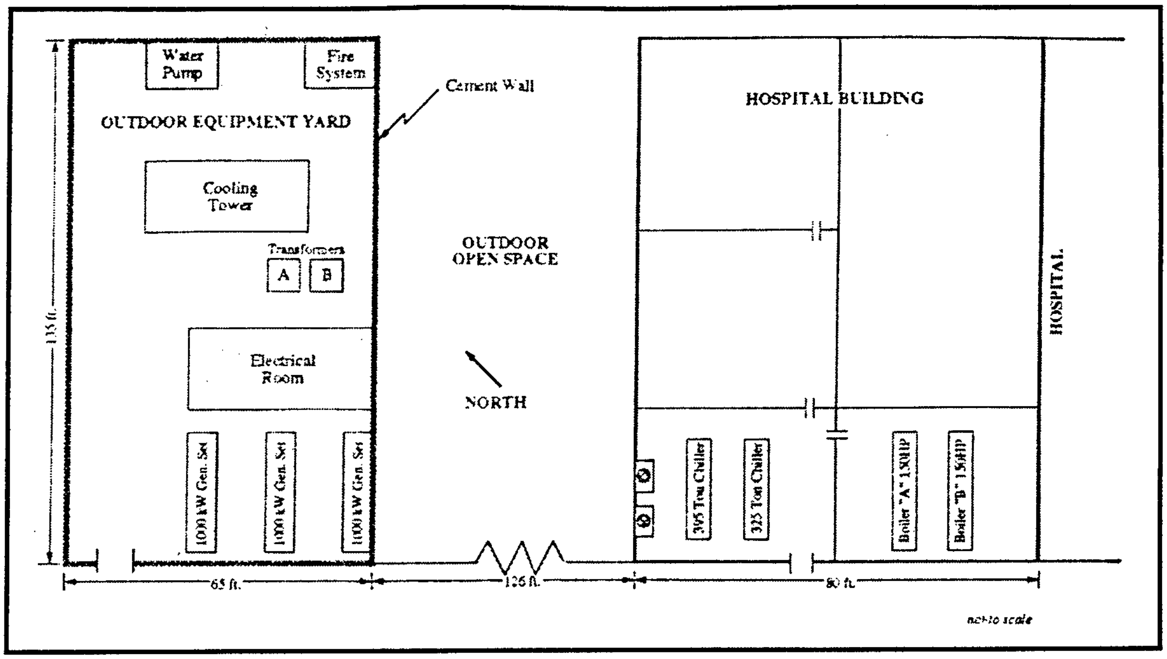


Figure 1. Layout of hospital facility.

Electrical System

The hospital electricity is supplied by two 480 volt/4000 amp service circuits. These circuits can be switched and supplied by either of the 12.4 kV/480 V transformers.

Steam/Hot Water System

The hospital has two Kewanee steam boilers that operate at about 100 psig. The boilers operate on natural gas and have a rated fuel input of 5,021 kBtu/hr. Steam from the boilers is used for sterilization, space conditioning, and domestic hot water. Each end use has a separate heat exchanger. Steam distribution for sterilization is through a closed loop system that circulates throughout the building. Domestic hot water is supplied at a temperature of approximately 140 °F.

Space Heating System

Space heating for the building is provided by a hydronic system. Hot water is supplied at 160 °F to the heating system while the return water temperature varies with building heating load. The design return temperature is 115 °F. Return water temperatures can range from 115 to about 150 °F.

Fuel Cell Location

It is proposed that the fuel cell be located against the outside northeast wall of the equipment yard. This location provides good access for installation and for visitors, as well as a storm drain for excess process water. At this location, the fuel cell enclosure would structurally fit in well with the site. A security fence around three sides of the fuel cell would be required. The existing sidewalk would have to be moved and a pad poured for the fuel cell, cooling tower, and storage tank.

Figure 2 shows the proposed electric and thermal runs for the fuel cell interfacing with the hospital. The electric run would be about 75 ft; the thermal run would be about 350 ft. Trenching will be required for both the electrical and thermal runs in an area where underground electrical and piping exists.

Fuel Cell Interfaces

It is recommended that the fuel cell be electrically connected to both 480-volt circuits feeding the hospital. The two circuits can presently be fed from either transformer. Figure 3 shows the proposed electrical interface. Assuming a building electric load factor of 50 percent (typical for hospitals) and an average demand of 347 kW (from Table 2), the hospital will use 95 percent of the fuel cell electric output.

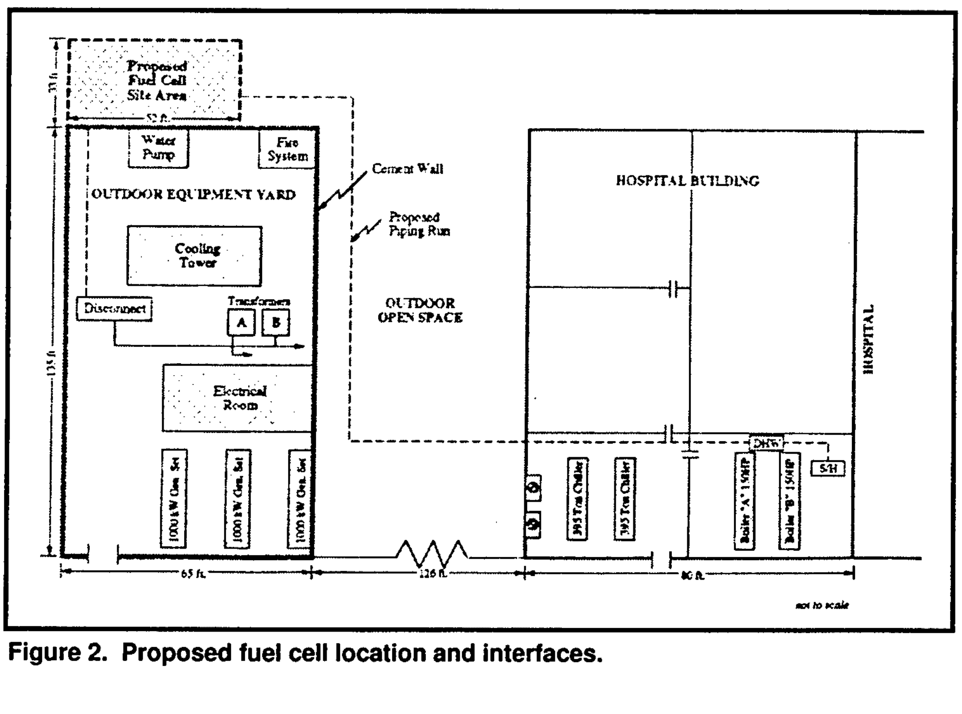


Figure 2. Proposed fuel cell location and interfaces.

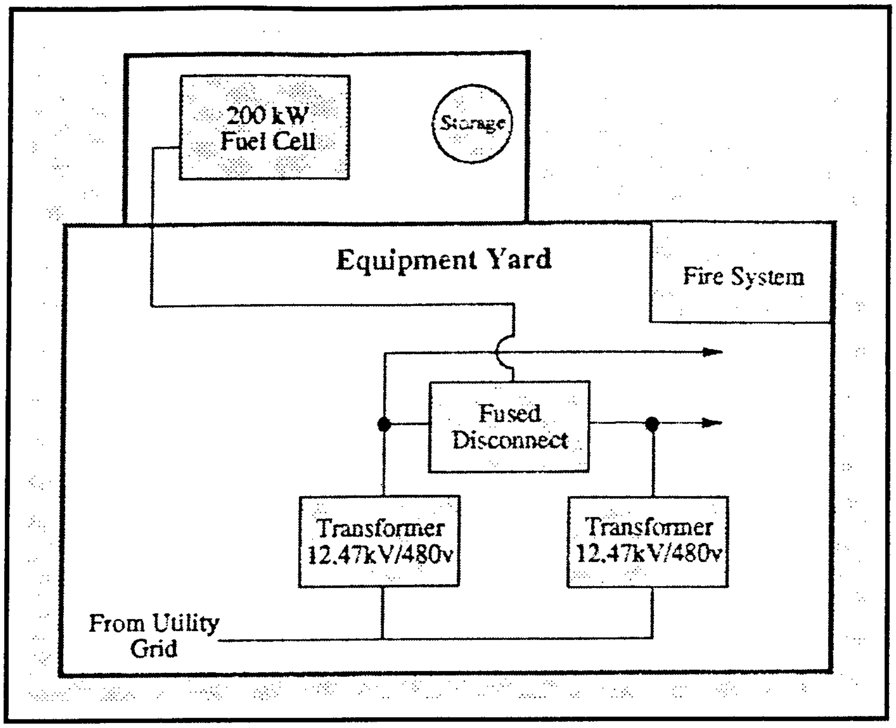


Figure 3. Fuel cell electric interface.

There are three possible fuel cell thermal interfaces at the hospital: (1) domestic hot water (DHW) make-up only, (2) DHW recirculation losses, and (3) space heating. The following paragraphs discuss each of these interfaces.

The DHW make-up only alternative is the simplest case. In this case, the DHW make-up water is rerouted through the fuel cell with a thermal storage tank and is fed to the hospital on demand. If the fuel cell system cannot meet the DHW load, the existing steam system will bring the water temperature up to the required 140 °F (Figure 4). Based on hospital gas usage from Table 4, the DHW load (make-up plus recirculating losses) is about 4,400 MBtu/yr. Based on previously measured hospital data (GRI 40 kW fuel cell field test), it is estimated that the make-up load is 75 percent, or 3,300 MBtu/yr. The fuel cell can supply all of the DHW make-up load using thermal storage. The fuel cell thermal utilization would be 60 percent at a 90 percent electric capacity factor for this interface (3,300 MBtu [700,000 Btu/hr * 8,760 hr/yr x 90% capacity factor] = 60 percent).

It is recommended that about 5,000-gal storage tank be installed. The tank sizing was calculated for the fuel cell system to meet the DHW load on a daily basis. To estimate the size of the tank, a typical hospital DHW usage profile was used (GRI 40 kW fuel cell field test). The profile shape was scaled to match the DHW use at the hospital, which is based on the gas bills.

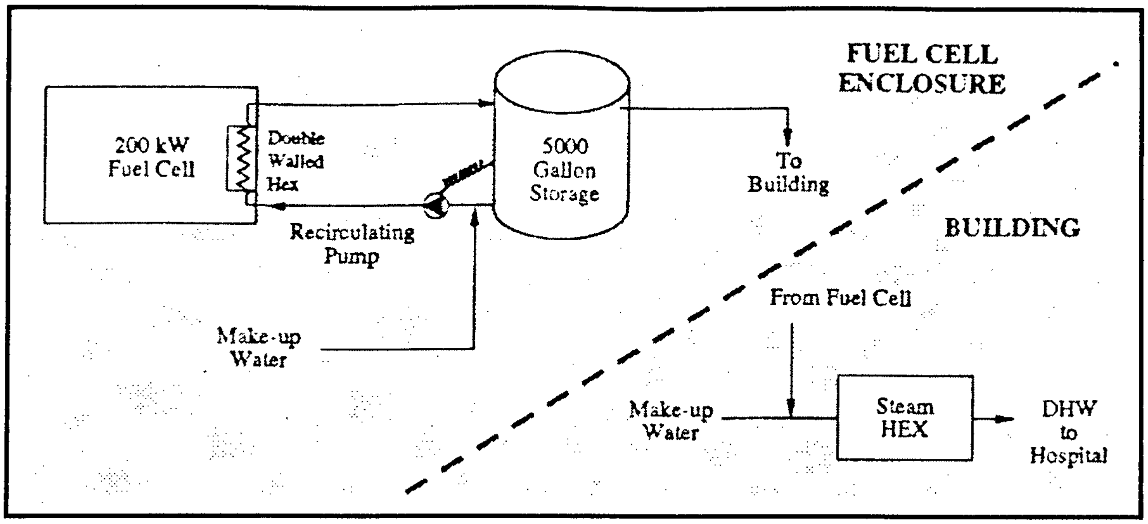


Figure 4. Fuel cell thermal interface—domestic hot water make-up only.

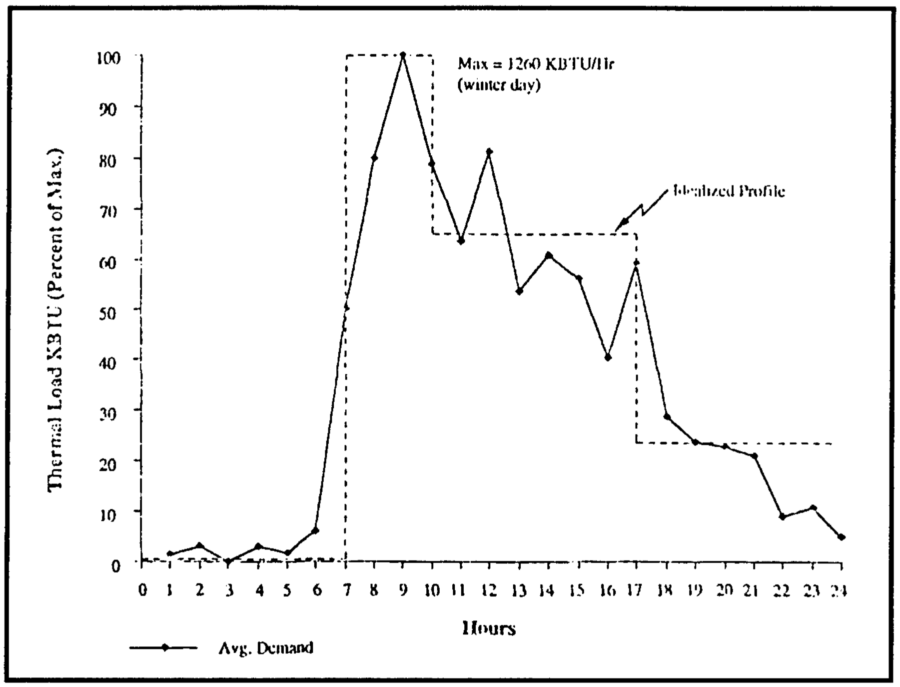


Figure 5. Daily thermal load—Hospital, 14 December 1984.

Figure 5 shows the DHW profile. The 5000-gal tank size was selected to meet the 3-hr peak usage from 7 a.m. to 10 a.m. The peak rate during this period is 1260 kBtu/hr, at a flow rate of about 1700 gal/hr. Assuming a 50 °F make-up water temperature and a 1700 gal/hr flow rate, the fuel cell supply temperature to the tank would be only 100 °F during this peak period. To meet the full 3-hr peak period, the tank was sized to supply 1700 gal/hr for 3 hr (5100 gal) at 140 °F. This is a conservative estimate of tank size. In the absence of measured usage data at the hospital, this approach provides an engineering estimate of the required tank size based on typical hospital loads.

The fuel cell system could also be interfaced with the DHW recirculating loop by adding a return water line and temperature controlled valve (Figure 6). When the DHW return temperature is less than the storage tank temperature, the recirculation flow would then be directed to the fuel cell storage tank. The fuel cell can supply heat for all of the DHW recirculation loses, even at return temperatures of 135 °F, which is typical of recirculation systems. Interfacing the fuel cell with both the DHW make-up and recirculation loss loads would increase the fuel cell thermal utilization to 80 percent (4,400 MBtu/yr / [700,000 Btu/hr * 8,760 hr/yr * 90 percent electric capacity factor]).

The third thermal interface option would he to interface with the space heating system as well as the DHW make-up load. To do this, a heat exchanger, circulating pump, and approximately a 350-ft piping run (with larger pipe) must be added (Figure 7). Based on the gas bills, it is expected that the space heating load is 1870 MBtu/yr and occurs from November through February. With the fuel cell meeting the DHW makeup load first and then the space heating system, a maximum of 820 MBtu/yr of fuel cell heat could be used for space heating based on a 115 °F return temperature. The total fuel cell thermal utilization would be 75 percent maximum for this interface ([3,300 MBtu + 820 MBtu]/yr / [700,000 Btu/hr * 8,760 hr/yr * 90 percent capacity factor] = 75 percent thermal utilization). However, as the space heating return temperature increases above the 115 °F design temperature, the amount of fuel cell heat utilized will decrease. Figure 8 shows the layout of the fuel cell site area located along the northeast wall of the equipment yard.

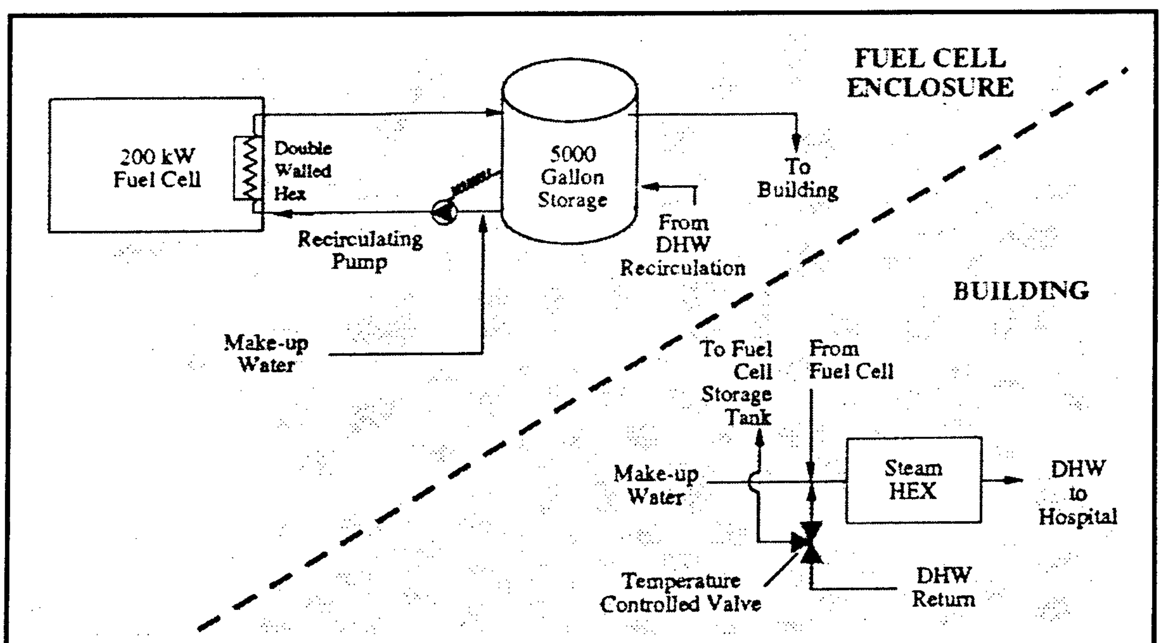


Figure 6. Fuel cell thermal interface—domestic hot water make-up and recirculation loop.

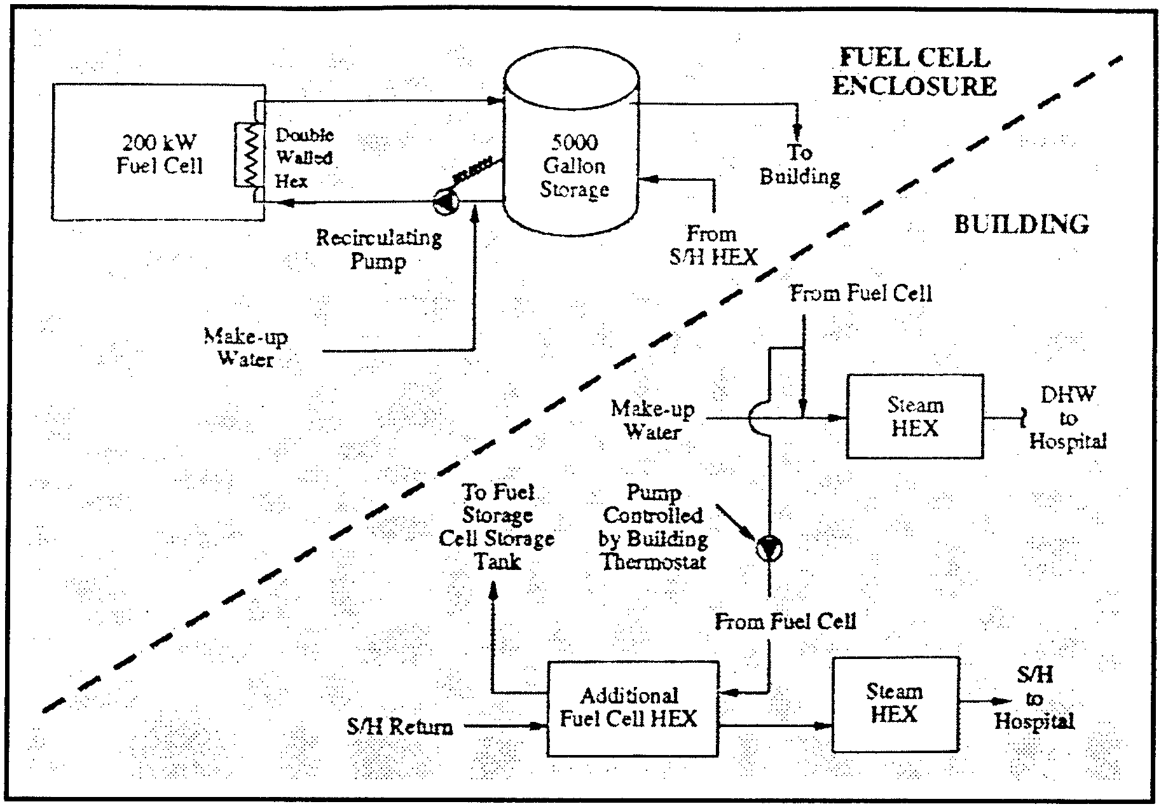


Figure 7. Fuel cell thermal interface—domestic hot water make-up and space heat.

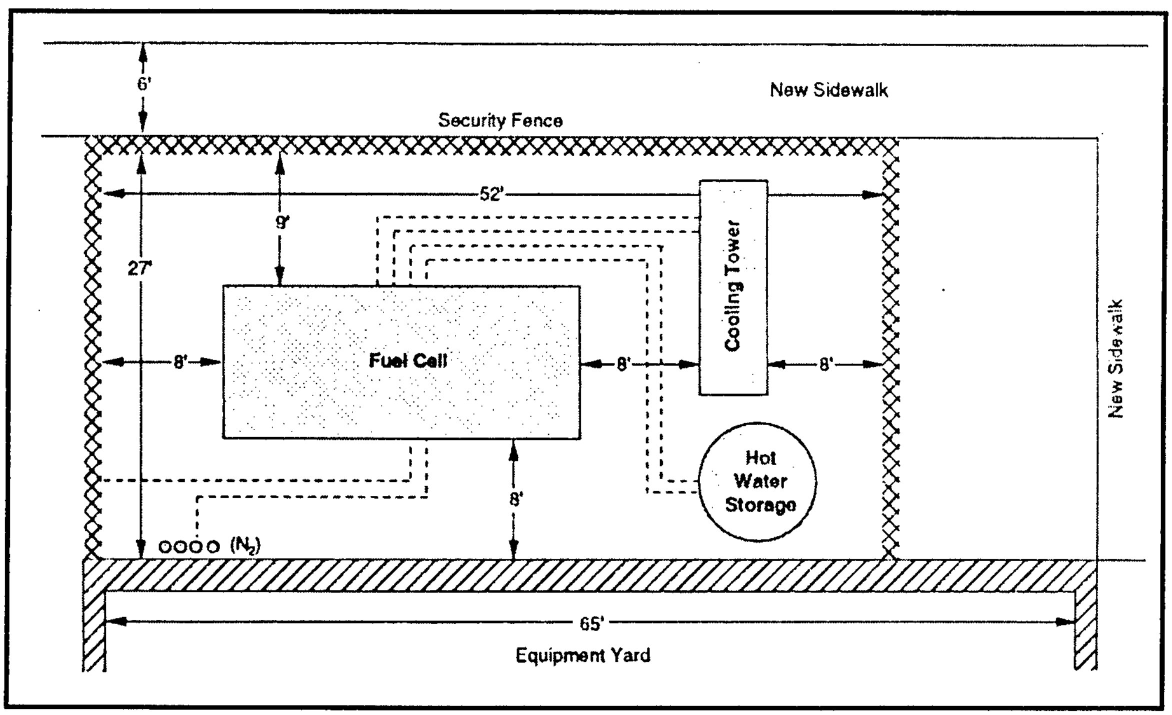


Figure 8. Fuel cell layout.

3 Economic Analysis

Energy savings were calculated based on projected energy utilization of the fuel cell output at the hospital. Site energy rates were used as the basis for calculating fuel cell savings.

The Site is located in Southern California Edison's (SCE) service territory and is billed under rate schedule TOU-8. Electricity costs under TOU-8 vary by season (winter/summer) and time of day (on-peak/mid-peak/off-peak). The site monthly average electric rate varied from 6.1 cents/kWh (February 1993) to 11.2 cents/kWh (September 1993). The average annual electricity cost for October 1992 through September 1993 was 8.5 cents/kWh. Table 5 lists electricity and energy consumption data for the entire Twentynine Palms facility.

The Site is supplied natural gas under three rate schedules. From Southern California Gas Company (SoCal Gas), GN-20 and a multi-family residential rate schedule apply. The Site also receives natural gas for its central plant using a direct purchase rate. Table 6 lists natural gas consumption for the Site under rate schedule GN-20. For GN-20, monthly average rates ranged from \$4.80/MBtu (November 1992) to \$5.73/MBtu (March 1993). The average annual gas rate was \$5.43/MBtu. For direct purchase of transportation natural gas, the Site pays approximately \$2.70/MBtu.

Table 5. Twentynine Palms Base electricity consumption.

Date	Billing Days	Peak kW	Total kWh	Total Amount	$/kWh
Sep 93	27	16,380	7,662,600	$859,345.17	$0.112
Aug 93	33	16,596	9,918,000	$1,031,142.00	$0.104
Jul 93	29	15,876	8,496,000	$914,822.26	$0.108
Jun 93	29	15,498	7,416,000	$703,244.37	$0.095
May 93	30	14,364	7,122,600	$465,739.86	$0.065
Apr 93	31	12,006	5,869,800	$376,611.46	$0.064
Mar 93	—	—	—	—	—
Feb 93	30	9,162	5,212,800	$318,655.19	$0.061
Jan 93	33	9,234	5,693,400	$364,574.56	$0.064
Dec 92	31	9,558	5,572,800	$380,308.46	$0.068
Nov 92	32	11,358	5,792,400	$391,085.83	$0.068
Oct 92	30	15,264	6,917,400	$624,425.18	$0.090
Total	335	13,209	75,673,800	$6,429,954.34	$0.085

Table 6. Twentynine Palms Base natural gas consumption.

Date	Therms	Amount	$/MBtu
Sep 93	25,241	$14,128.07	$5.60
Aug 93	21,711	$12,210.37	$5.62
Jul 93	23,577	$13,237.53	$5.61
Jun 93	23,160	$13,010.75	$5.62
May 93	30,709	$16,322.44	$5.32
Apr 93	44,051	$23,244.54	$5.28
Mar 93	61,824	$35,403.91	$5.73
Feb 93	91,623	$52,056.48	$5.68
Jan 93	124,035	$70,169.29	$5.66
Dec 92	125,290	$65,227.55	$5.21
Nov 92	61,771	$29,655.87	$4.80
Oct 92	16,901	$8,397.35	$4.97
Total	649,893	$353,064.15	$5.43

Table 7 lists SCE's TOU-8 rate schedule along with estimated electric savings based on a fuel cell capacity factor of 90 percent. Summer months are June through September. The on-peak period lasts for 6 hr/weekday during the summer period. The mid-peak period lasts for 9 hr/weekday during the summer period and 13 hr/weekday during the winter period. The off-peak period includes the remaining hours including weekends and holidays. Using the hours per period in a year and the demand and energy rates per period, electric savings were calculated for the fuel cell. It was assumed that fuel cell outage hours during the on/mid/off-peak periods occurred at the same percentages shown in Table 7. In other words, outage hours were not weighted more heavily in any individual period, but proportional to the number of period hours in a year. Total electric savings for the 90 percent electric capacity factor case was $114,281 including demand savings.

Based on the projected fuel cell electric capacity factor and thermal utilization for the thermal design schemes discussed above, the economic savings from a 200 kW fuel cell were calculated. Table 8 lists the electric and thermal energy savings and the input natural gas costs for the fuel cell installation. For the DHW make-up plus recirculation interface the total net savings based on a 90 percent capacity factor and an 80 percent thermal utilization would be $64,919 in the first year. For the DHW plus space heating interface case, total net savings based on a 90 percent capacity factor and 75 percent thermal utilization of the fuel cell thermal output was $62,893 in the first year. By comparison, the DHW make-up water only case had a 60 percent thermal utilization resulting in a first year net savings of $56,947.

The cost of the additional piping, pump and control valve required for the DHW recirculation interface is estimated at about $10,000. The additional energy bill savings is estimated to be about $8,000/yr ($64,919 – $56,947). However, it is not recommended that this interface be used without additional data on the recirculation losses.

The cost of the additional piping, pump and heat exchanger required for the space heating interface would be approximately $14,000. The energy bill savings from the space heating interface is around $5,900 ($62,893 – $56,947) per year over the DHW make-up water case. It is not recommended that the fuel cell be thermally interfaced with the space heating system without first verifying the number of operating hours and heating rate (return temperature) for the space heating system.

This economics analysis is intended to be a general overview. For the first 5 years, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net energy savings. Since load profile data were not available, energy savings could vary depending on actual electrical and thermal utilization.

Table 7. SCE TOU-8 rate schedule and hospital electric savings.

Category	Summer	Winter	Summary
Demand			
On-Peak	$1890	$315	
Mid-Peak	$2.35		
Off- Peak	—	—	
Energy			
On-Peak	$013752	—	
Mid-Peak	$006517	$007688	
Off-Peak	$004077	$004335	
Hours/year			
On-Peak	498		5.7%
Mid-Peak	747	2,197	33.6%
Off-Peak	I&II	3,707	60.7%
	2856	5,904	100.0%
Savings/year (90% ELF)			
On-Peak	$12,327.29	—	
Mid-Peak	$8,762.76	$30,402.96	
Off-Peak	$11,822.48	$28,925.72	
	$32,912.53	$59,328.68	$92,241.22
Demand (200 kW)	*$17,000*	*$5,040*	*$22,040*
Total Savings	***$49,912.53***	***$64,368.68***	***$114,281.22 ($kWh = $0. 0725)***

Table 8. Economic savings of fuel cell design alternatives.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat. Gas Cost	Net Savings
A-Max. thermal	90%	100%	1,576,800	7,357	$114,281	$39,948	$81,220	$73,009
A-DHW make-up + recirc.	90%	80%	1,576,800	5,867	$114,281	$31,858	$81,220	$64,919
A-DHW make-up + heat	90%	75%	1,576,800	5,494	$114,281	$29,832	$81,220	$62,893
A-DHW make-up	90%	60%	1,576,800	4,399	$114,281	$23,886	$81,220	$56,947
B-Max. thermal	90%	100%	1,576,800	7,357	$103,261	$39,948	$81,220	$61,989
B-DHW make-up + recirc.	90%	80%	1,576,800	5,867	$103,261	$31,858	$81,220	$53,899
B-DHW make-up + heat	90%	75%	1,576,800	5,494	$103,261	$29,832	$81,220	$51,873
B-DHW make-up	90%	60%	1,576,800	4,399	$103,261	$23,886	$81,220	$45,927
C-Max. thermal	90%	100%	1,576,800	7,357	$92,241	$39,948	$81,220	$50,969
C-DHW make-up + recirc.	90%	80%	1,576,800	5,867	$92,241	$31,858	$81,220	$42,879
C-DHW make-up + heat	90%	75%	1,576,800	5,494	$92,241	$29,832	$81,220	$40,853
C-DHW make-up	90%	60%	1,576,800	4,399	$92,241	$23,886	$81,220	$34,907

Assumptions:

Input Natural Gas Rate: $5.43/MBtu
Displaced Electricity Rate: TOU-8
Displaced Thermal Gas Rate: $5.43/MBtu
Fuel Cell Thermal Output: 700,000Btu/hr
Fuel Cell Electrical Efficiency: 36%
Seasonal Boiler Efficiency: 75%
Case A: full fuel cell demand savings
Case B: 50% of full fuel cell demand savings
Case C: zero fuel cell demand savings
ECF: Fuel cell electric capacity factor
TU: Thermal Utilization

4 Conclusions and Recommendations

This study concludes that the new Naval Hospital at Twentynine Palms represents a good location for a fuel cell application.

It is recommended that the entire electric load of the hospital be supplied by the fuel cell. It is also recommended that only the DHW make-up water system be tied in with an ~5,000-gal capacity storage tank interfaced with the fuel cell's thermal output. If data can confirm the estimated additional fuel cell thermal utilization from interfacing with the DHW recirculation loop or the space heating system, then these options should be considered. The DHW recirculation load is more attractive than the space heat option because a second heat exchanger would not be necessary. The location of the fuel cell should be the area that is just northeast of the outdoor equipment yard. Piping interfaces can be made to the hospital by trenching in the open space between the hospital and equipment yard.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **Twentynine Palms Marine Corp. Base**
Location: **Twentynine Palms, CA** Contacts: **Stu Hammons/Luke Wren**

1. Electric Utility: **So. Cal. Edison** Rate Schedule: **TOU-8**
   Contact: **Wayne Hofeldt**

2. Gas Utility: **So. Cal. Gas** Rate Schedule: **Multi-family Res. General Service Direct Supply**
   Contact: **Terence Mack**

3. Available Fuels: **Diesel fuel #2** Capacity Rate:

4. Hours of Use and Percent Occupied:
   Weekdays ________ Hrs. **24**
   Saturday ________ Hrs. **24**
   Sunday ________ Hrs. **24**

5. Outdoor Temperature Range: **10 - 120 °F**

6. Environmental Issues: **Mojave Air Quality Management District, Richard Wales (619) 245-5402**

7. Backup Power Need/Requirement: **Three - 1,000 kW Caterpillar generator sets**

8. Utility Interconnect/Power Quality Issues:

9. On-site Personnel Capabilities: **So. Cal. Gas will perform the contract maintenance**

10. Access for Fuel Cell Installation: **Proposed site is right next to road**

11. Daily Load Profile Availability: **None available**

12. Security: **Install fence**

Site Layout

Facility Type: **Hospital Facility** Age: **< 1 year**

Construction: **Block**

Square Feet: **190,000 sq ft (39 bed facility with clinics/support facilities)**

See Figures 1 & 2

Show:

- **electrical/thermal/gas/water interfaces and length of runs**
- **drainage**
- **building/fuel cell site dimensions**
- **ground obstructions**

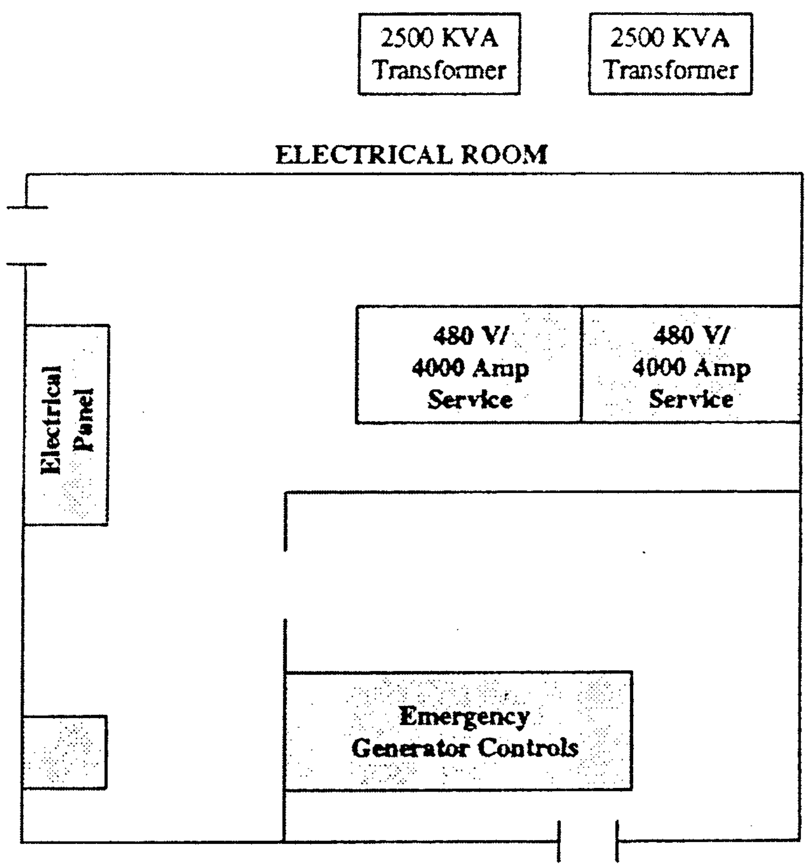
Electrical System

Service Rating: **480 Volt/4,000 Amp service (2), 2,500 kVA transformers (2)**

Electrically Sensitive Equipment: **Unknown**

Largest Motors (hp, usage): **75 HP pump motor for fire sprinklers**

Grid Independent Operation?: **Fuel cell will feed both hospital and Base**



Steam/Hot Water System

Description: **Kewanee steam boilers (2) - 100 psig**

System Specifications: **Boiler feed water heater with condensate return**

Fuel Type: **Natural Gas**

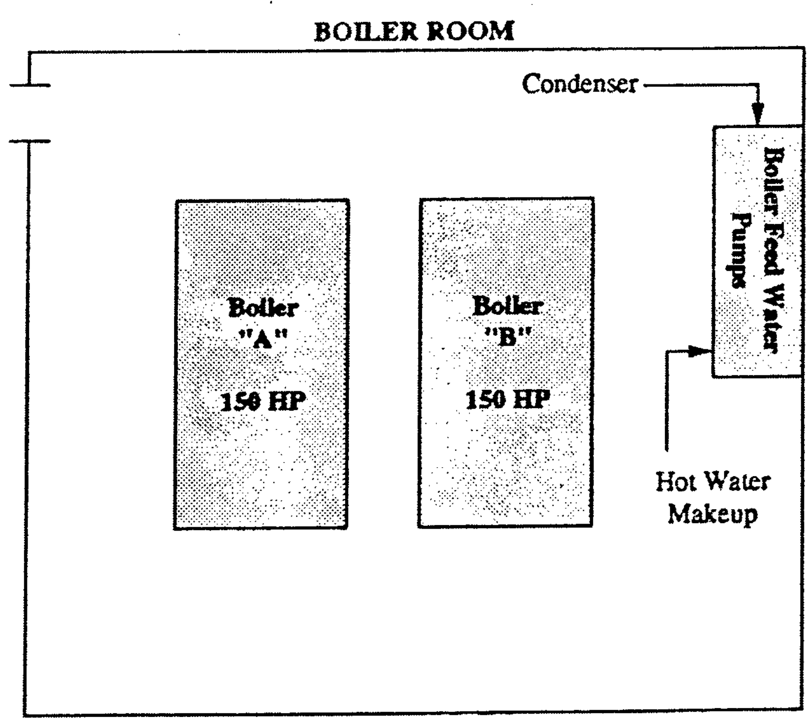
Max Fuel Rate: **5,021 kBtu/hr**

Storage Capacity/Type: **None; on demand**

Interface Pipe Size/Description: **2.5 in. copper**

End Use Description/Profile:

Steam is used for sterilization, space conditioning and domestic hot water. Each end use has its own heat exchanger. Steam distribution is a closed loop system. Domestic hot water supply temperature is 140 °F.

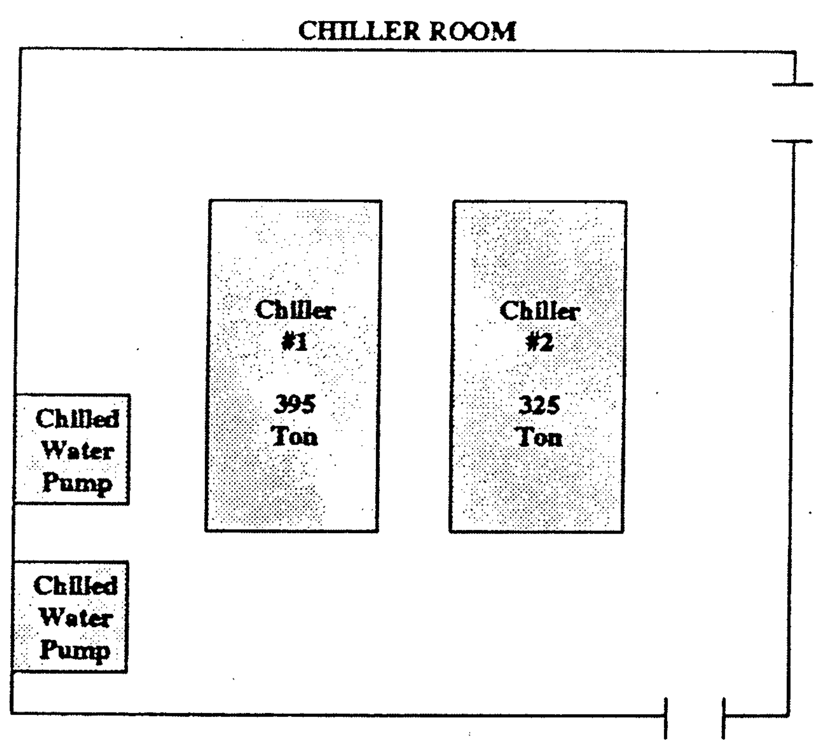


Space Cooling System

Description: **Central centrifugal chillers (2)**

Air Conditioning Configuration:
Type: **Centrifugal chilled water loop system**
Rating: **325 Ton/395 Ton**
Make/Model: **York**

Seasonality Profile: **New building; no load data. Climate is over 100 °F for much of the summer.**



Space Heating System

Description: Heat exchanger of steam boiler; on demand system

Fuel: Natural gas

Rating: **632 gal/minute**

Water supply Temp: **160 °F**

Water Return Temp: **115 °F**

Make/Model:

Thermal Storage (space?): **No storage; very little space**

Seasonality Profile: **None available**

Billing Data Summary

ELECTRICITY

	Period	kWh	kW	Cost
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				
11.				
12.				

NATURAL GAS

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

OTHER

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

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14. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93). CERL has selected and evaluated application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers for 29 of 30 commercially available fuel cell power plants and their thermal interfaces installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at the Naval Hospital at Twentynine Palms, CA, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

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Marine Corps Air Ground Combat Center, Twentynine Palms, CA

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